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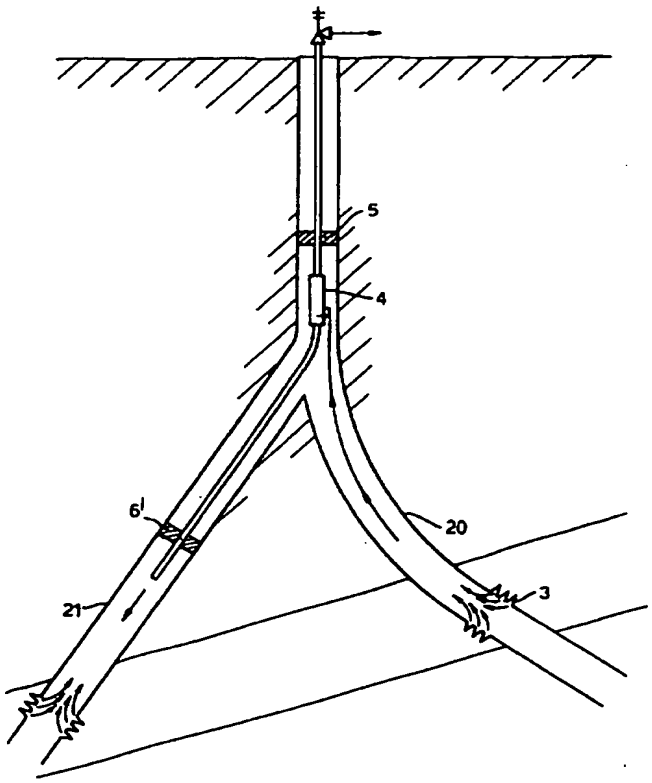
(54) Title: A METHOD OF SEPARATING PRODUCTION FLUID FROM AN OIL WELL

(57) Abstract

A method of separating oil, water and sand in a production fluid. The production fluid is fed through a downhole liquid/liquid hydrocyclone (9). An oil enriched stream from the hydrocyclone (9) is pumped to the surface, while an oil depleted stream is fed to a downhole solid/liquid hydrocyclone (12). Here, the bulk of the solids are separated from the water, so that water which is substantially free of solids can be transported to a downhole disposal site (14).



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A METHOD OF SEPARATING PRODUCTION FLUID FROM AN OIL WELL

The present invention relates to a method of separating production fluid from an oil well.

Increasingly, oil producers are looking for ways to produce oil from wells in which the production fluid has a high water cut efficiently enough to make the cost of the production economic. One way of achieving this is shown in US-A-4738779, which discloses the use of a liquid/liquid hydrocyclone within a well bore in order to provide initial separation of some of the water from the production fluid to reduce the quantity of production fluid which needs to be transported to the surface. The separated water is returned to the oil reservoir, or to another reservoir which has been exhausted.

According to the present invention, a method of separating oil well production fluid containing oil, water and sand comprises transporting the production fluid to a downhole liquid/liquid hydrocyclone, separating the production fluid in the liquid/liquid hydrocyclone into an oil enriched stream at the hydrocyclone overflow, and a water enriched stream at the hydrocyclone underflow, transporting the oil enriched stream to the surface, transporting the water enriched stream to a downhole solid/liquid hydrocyclone, separating the water enriched stream in the solid/liquid hydrocyclone into a solid depleted stream at the overflow, and a solid enriched stream at the underflow, and transporting the solid depleted stream to a downhole disposal site.

By providing a solid/liquid hydrocyclone in this way, the method of the present invention ensures that the solid depleted stream which is fed to the disposal site is generally free of solids. This avoids a problem of the prior art, namely the blocking of pores in the rock at the disposal site, which hinders the reinjection of the separated water. Also, in the prior art, in high solids

producing wells, the wellbore itself can become blocked below the level of the hydrocyclones.

To some extent, the pressure of the production fluid can be used to drive the two hydrocyclones. However, additional pumps are generally necessary, for example to pump the production fluid in the line feeding the liquid/liquid hydrocyclone, or to pump the oil enriched stream being transported to the surface.

The solid enriched stream may be disposed of in a suitable underground site. However, preferably, the solid enriched stream is transported to the surface for disposal and/or further treatment. The oil enriched stream and the solid enriched stream may be transported separately to the surface. However, the two streams can be combined to be transported jointly to the surface.

This arrangement forms further aspect of the present invention which can be defined as an apparatus for separating a mixture containing oil, water and sand, the apparatus comprising a liquid/liquid hydrocyclone for separating the mixture into an oil enriched stream at the hydrocyclone overflow, and a water enriched stream at the hydrocyclone underflow; a first duct leading from the hydrocyclone overflow for the transport of the oil enriched stream; a second duct leading from the hydrocyclone underflow for the transport of the water enriched stream; a solid/liquid hydrocyclone, fed with the water enriched stream in the second duct, for separating the water enriched stream into a solid depleted stream at the overflow, and a solid enriched stream at the underflow; and a third duct leading from the solid/liquid hydrocyclone underflow, and joining with the first duct, so that the oil enriched stream and the solid enriched stream are transported together downstream of the join between the first and third ducts.

The disposal site for the solid depleted stream may be an adjacent reservoir which has been exhausted. Preferably, however, the method of the present invention further

comprises drilling two bores from one surface well into the same production formation, and installing the hydrocyclones into the well so that the production fluid to be treated is taken from a first bore, and the solid depleted stream is returned via the second bore to the formation at a location below that at which the production fluid is removed. This ensures that the bulk of the fluids removed from the formation are returned, so that the formation pressure is maintained and dissolved gas remains in solution. Also, the residual oil in the formation is "swept" towards the first bore.

Two examples of an apparatus for separating production fluid with which the method according to the present invention can be performed will now be described with reference to the accompanying drawings, in which:

Fig. 1 is a schematic diagram of a first separating apparatus; and

Fig. 2 is a schematic diagram of a second separating apparatus.

As shown in Fig. 1, a well bore casing 1 penetrates into a production formation 2, and is provided with perforations 3 through which production fluid comprising oil, water and sand from the production formation enters the casing 1. Within the casing 1, a separator/pump module 4 is sealed by upper 5 and lower 6 packers.

The separator/pump module 4 comprises a first stage pump 7 which has an intake 8 for the production fluid within the casing 1. The pump 7 pumps the production fluid to a liquid/liquid hydrocylone 9 along an inlet line 10. The mixture being fed to the liquid/liquid hydrocyclone generally has a much larger proportion of water than of oil, so that, in the liquid/liquid hydrocylone 9, the mixture is separated so that the bulk of the water, together with the sand reports to the underflow, while an oil enriched stream reports to the overflow.

The stream from the underflow is fed along the first underflow line 11 to a solid/liquid hydrocyclone 12, in

which the solid sand particles are separated from the bulk of the water. The bulk of the water reports to the overflow of the solid/liquid hydrocyclone 12, and flows out along reject line 13, from where it is reinjected into a water disposal zone 14 which may be a part of the production formation, or may be a separate site. As this water is substantially free of solids, problems with clogging the water disposal zone 14 are avoided.

The solid slurry from the underflow of the solid/liquid hydrocyclone 12 is fed along a second underflow line 15, where it is combined with the flow from the overflow of the liquid/liquid hydrocyclone 9 in overflow line 16. The flow from the two lines is pumped to the surface by a second stage pump 17. This pump 17, as well as the first stage pump 7 are driven by a common pump motor 18. The two lines can be readily combined as the pressure drop across the inlet and overflow outlet of the liquid/liquid hydrocyclone 9 is less than or substantially equal to the combined pressure drop across the inlet and underflow outlet of the liquid/liquid hydrocyclone 9 and across the inlet and underflow outlet of the solid/liquid hydrocyclone 12.

A sealed sliding joint 19 is provided between the separator/pump module 4 and the packer 6.

At the surface, further processing of the combined oil enriched stream and solid stream is carried out in conventional production facilities.

Fig. 2 shows a modified version of the arrangement shown in Fig. 1. In this arrangement, two bores 20, 21 are drilled from a single surface wellbore. The first bore 20 is provided with production fluid perforations 3 in the production formation, in the same way as Fig. 1. The production fluid is transported to the separator/pump module 4 which is constructed in the same way as that shown in Fig. 1. In Fig. 2, the lower packer 6' is provided in the second bore 21. The bulk of the water, which is substantially free of solids, is produced at the overflow

of the solid/liquid hydrocyclone and is fed along the second bore 21 through the lower packer 6, for reinjection into the production formation at a location lower than the location from which the production fluid is extracted. The effect of this is to replace the removed production fluid, and sweep the residual oil in the rock towards the production well bore.

CLAIMS

1. A method of separating oil well production fluid containing oil, water and sand comprising transporting the production fluid to a downhole liquid/liquid hydrocyclone (9), separating the production fluid in the liquid/liquid hydrocyclone into an oil enriched stream at the hydrocyclone overflow (16), and a water enriched stream at the hydrocyclone underflow (11), transporting the oil enriched stream to the surface, transporting the water enriched stream to a downhole solid/liquid hydrocyclone (12), separating the water enriched stream in the solid/liquid hydrocyclone into a solid depleted stream at the overflow (13), and a solid enriched stream at the underflow (15), and transporting the solid depleted stream to a downhole disposal site (14).

2. A method according to claim 1, wherein the production fluid is pumped in a line (10) feeding the liquid/liquid hydrocyclone (9).

3. A method according to claim 1 or claim 2, wherein the oil enriched stream is pumped to the surface.

4. A method according to any one of the preceding claims, wherein the solid enriched stream is transported to the surface for disposal and/or further treatment.

5. A method according to any one of the preceding claims, further comprising the steps of drilling two bores (20,21) from one surface well into the same production formation, and installing the hydrocyclones (9,12) into the well so that the production fluid to be treated is taken from a first bore (20), and the solid depleted stream is returned via the second bore (21) to the formation at a location below that at which the production fluid is removed.

6. An apparatus for separating a mixture containing oil, water and sand, the apparatus comprising a liquid/liquid hydrocyclone (9) for separating the mixture into an oil enriched stream at the hydrocyclone overflow, and a water enriched stream at the hydrocyclone underflow; a first duct (16) leading from the hydrocyclone overflow for the transport of the oil enriched stream; a second duct (11) leading from the hydrocyclone underflow for the transport of the water enriched stream; a solid/liquid hydrocyclone (12), fed with the water enriched stream in the second duct, for separating the water enriched stream into a solid depleted stream at the overflow, and a solid enriched stream at the underflow; and a third duct (15) leading from the solid/liquid hydrocyclone underflow, and joining with the first duct (16), so that the oil enriched stream and the solid enriched stream are transported together downstream of the join between the first and third ducts.

Fig.1.

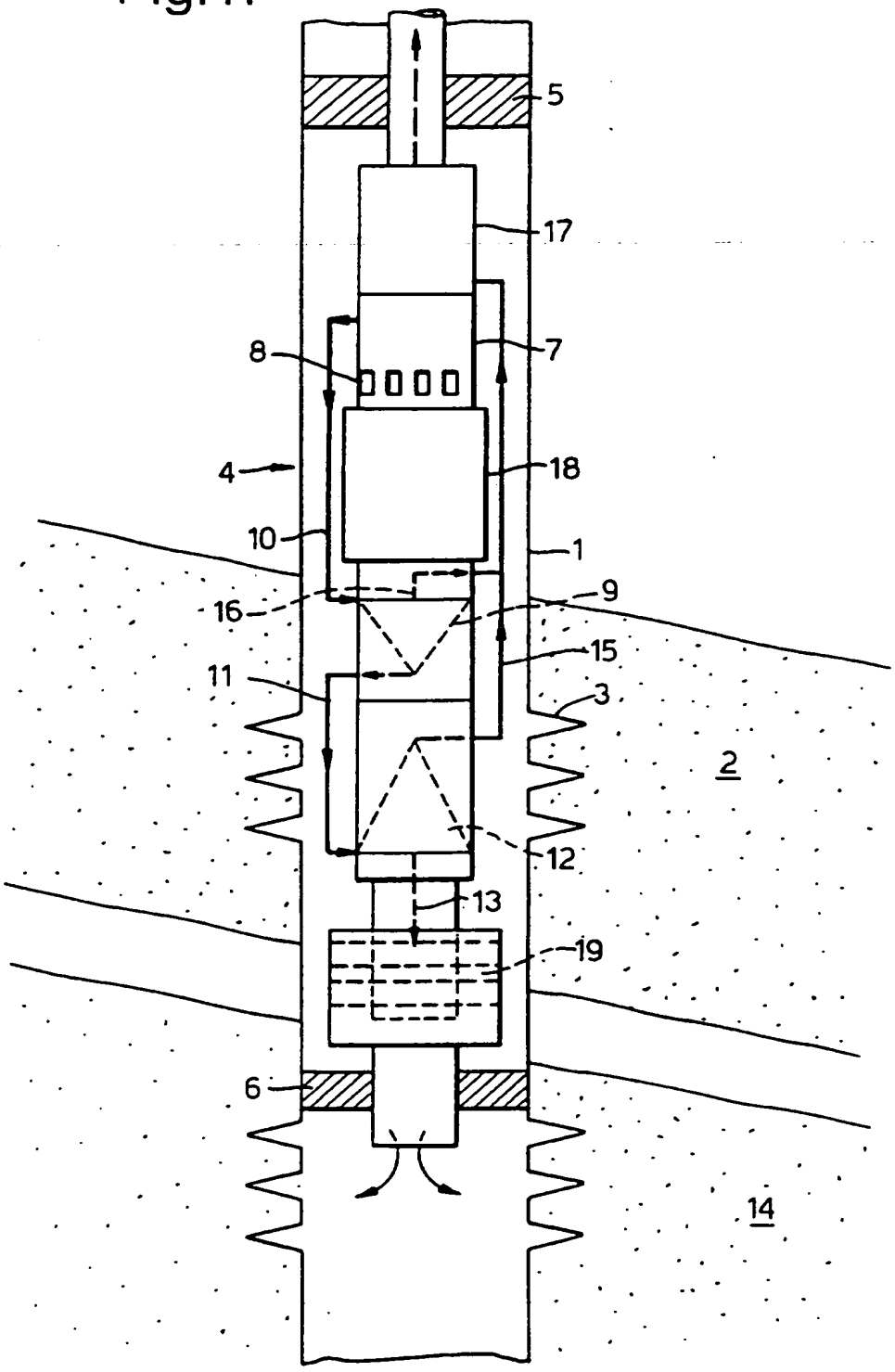
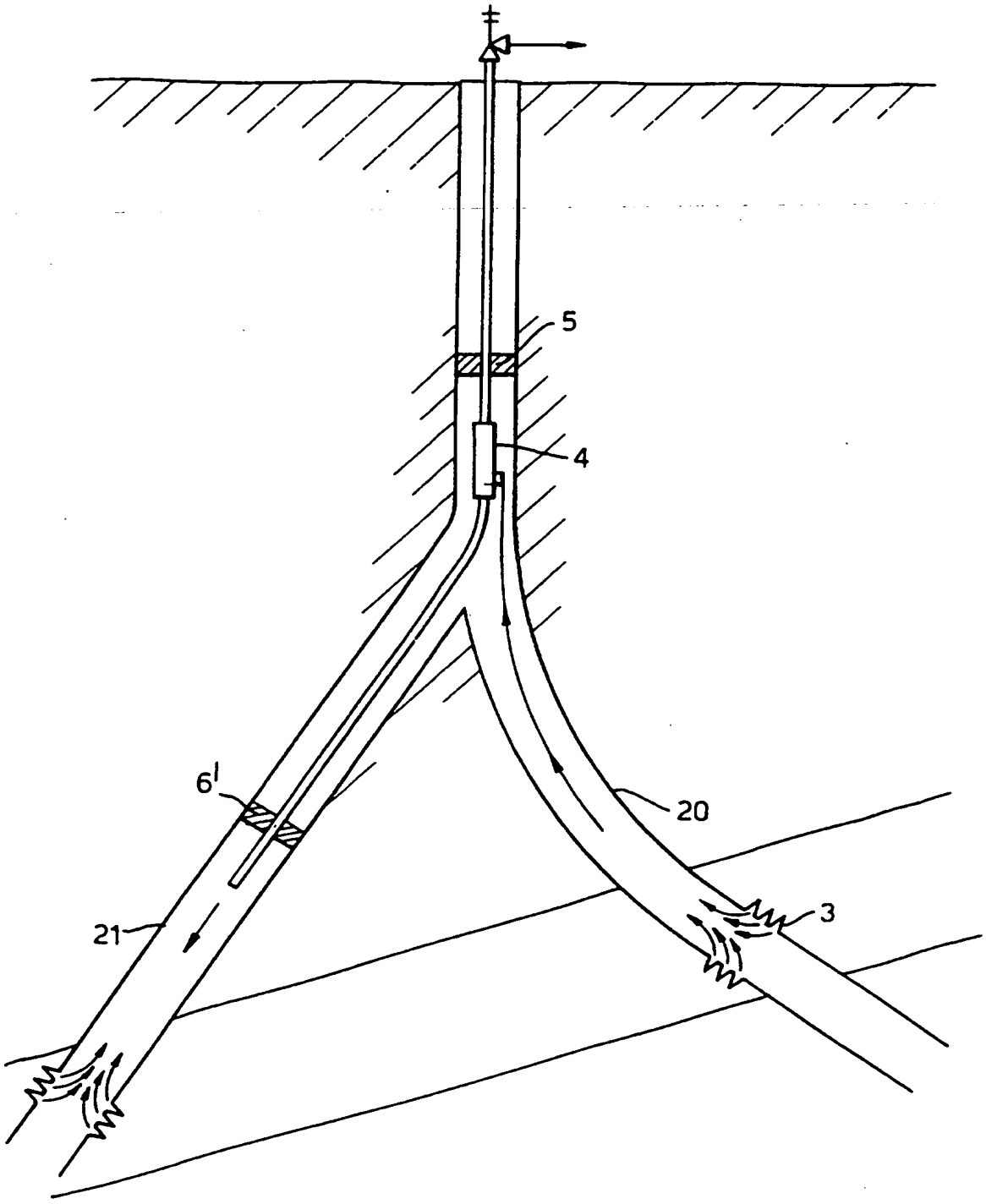


Fig.2.



INTERNATIONAL SEARCH REPORT

Int ional Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 E21B43/40 E21B43/38 B04C5/26 B01D17/035

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 E21B B04C B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	OFFSHORE (INC. THE OILMAN), vol. 55, no. 6, 1 June 1995, page 16 XP000512449 "DOWNHOLE SEPARATOR USES HYDROCYCLONE, ZONE DISCHARGE" ---	1-3,6
A	US 4 793 408 A (MIFFRE HUBERT) 27 December 1988 see column 6, line 61 - column 7, line 20 see column 7, line 27-33 see column 8, line 2-12 see figures 6,7 --- -/--	5

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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